1.4 Getting a Handle on Time

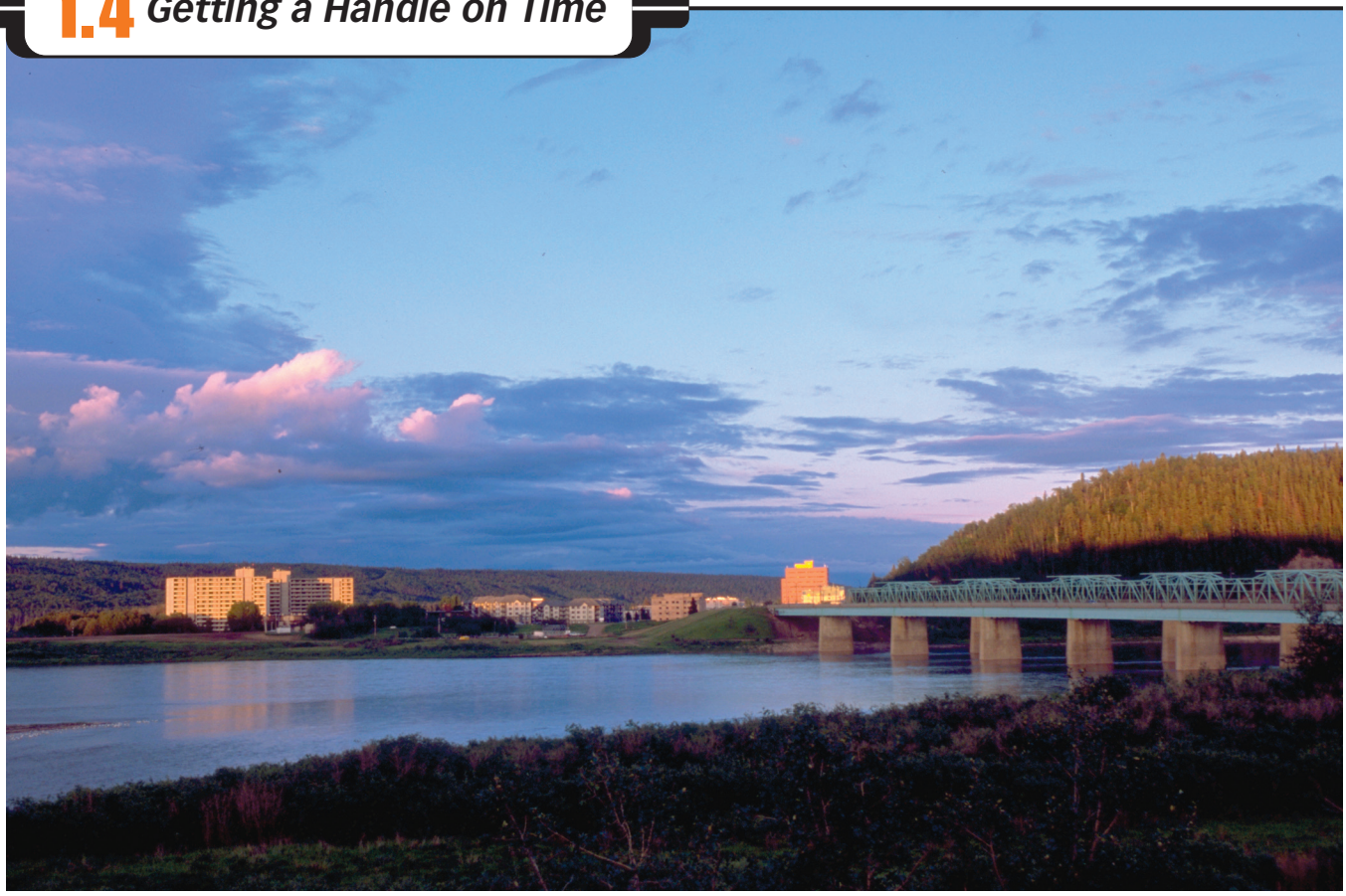


Figure C1.27: Fort McMurray is located at the junction of the Clearwater and Athabasca rivers.

In addition to its proximity to Alberta's oil-sand deposits, which is the world's single largest deposit of oil, Fort McMurray is known for its picturesque setting in northern Alberta's boreal forest. Since it is located at the junction of the Clearwater and Athabasca rivers, local residents can take advantage of these watery highways. If you travel by canoe north along the Athabasca, you can actually see outcrops of oil sand protruding from the river bank. How did such a valuable resource become deposited in the ground under the forests that surround Fort McMurray? Did a catastrope occur that created the oil sands?

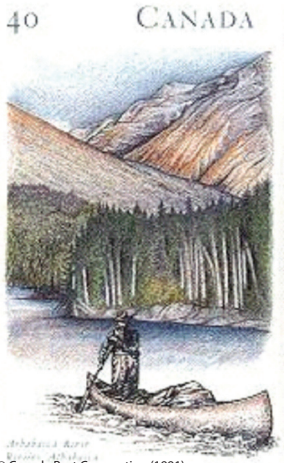


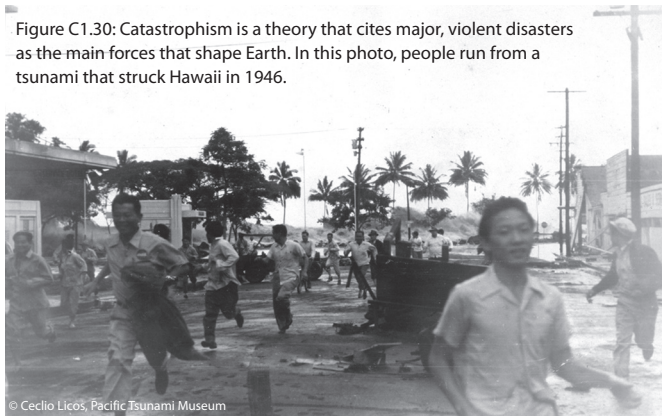
Figure C1.28: A canoe on the Athabasca is shown.

© Canada Post Corporation (1991). Reproduced with permission.

Figure C1.29: The Athabasca River flows through a major portion of Alberta.

Forces of Catastrophe

Figure C1.30: Catastrophism is a theory that cites major, violent disasters as the main forces that shape Earth. In this photo, people run from a tsunami that struck Hawaii in 1946.



© Cecilio Licos, Pacific Tsunami Museum

During the time of William Smith (1769–1839), and late into the nineteenth century, many geologists considered violent catastrophes such as earthquakes, volcanic eruptions, enormous floods, meteorite impacts, and upheavals of Earth's crust, to be the main mechanisms of past change. In fact, Smith himself proposed that the sedimentary rock layers he mapped were deposited over England by a series of catastrophic floods. These violent explanations are now called catastrophist theories. A main component of catastrophist theories in the eighteenth and nineteenth centuries is that they involve processes of a different type or intensity than those observed in the present.

Try This Activity

Imagine This: Catastrophic Events

Figures C1.31 shows some of Alberta's most distinctive landmark features. They make you think, how did that get there?

1. Using only catastrophic events, describe plausible explanations for the appearance of these three geological features. You may have to use your imagination to think of events that could be responsible for each of these landmarks.
2. Ask your teacher or use the Internet to find the current scientific explanations of how these features formed. Distinguish the general differences between your catastrophic explanations and current scientific explanations.

Science Skills

✓ Analyzing and Interpreting

Figure C1.31: Note the landmarks from the left. The hoodoos near Drumheller resemble the surface of an alien planet. Majestic Mount Rundle towers over the town of Banff. Strange spherical rocks up to 2.5 m in diameter appear to be strewn about at Red Rock Coulee in southern Alberta.

How Much Time?

Early theories of catastrophism fit in well with human experience. If you ask an 80-year-old woman what changes she has noticed in the landscape during her lifetime, you may hear, "The trees are larger," or "The city sure has grown," or "It seemed to snow a lot more when I was younger."

In the time span of one lifetime, the processes that go on day to day seem too slow to lay down hundreds of metres of sedimentary rock or to lift up mountains. Perhaps catastrophist theories dominated geological discussions for well over 100 years because they fit in well with the common belief that Earth was only several thousand years old.

The processes at work in the present seem too weak and slow to explain evidence of a dramatic change in Earth's past. It's hard to imagine that the slow processes observed in the present could have resulted in the badlands, Mount Rundle, or Red Rock Coulee.

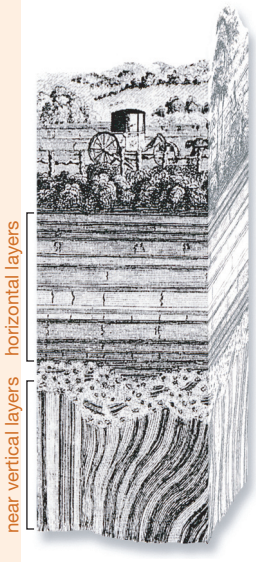


Figure C1.32: James Hutton observed complex geological histories recorded in rock strata.

Complex Histories

James Hutton (1726–1797) was a geologist who had opinions contrary to the dominant catastrophist theories of his time. He believed that to unlock the mysteries of the past, you must understand the processes at work in the present. This was the birth of **uniformitarianism**, and Hutton's work is considered by many historians to be the birth of modern geology. Hutton travelled throughout the countryside of Scotland and documented the processes he observed. Because geological change occurs so slowly, he had to rely on rock strata as a record of past events. Hutton was aware of Steno's law of superposition and applied it to rock strata. As an example, he observed nearly vertical layers of rock beneath horizontal layers. This led him to first propose that the bottom layers were originally deposited horizontally but were subsequently tilted. Then, after a long period of erosion, many layers were deposited horizontally on top. The top surface of the lower vertical layers is called an **unconformity**. In this case, the unconformity was likely caused by erosion. If the erosion was caused by a retreating ice sheet, it would also explain the layer peppered with gravel and boulders above the unconformity.

- uniformitarianism: the principle that the geological processes in action today have always fundamentally operated in the same way throughout Earth's history
- unconformity: a surface in a rock sequence that represents a break in the pattern due to erosion or a lack of deposition

Practice

Figure C1.33 is a geological profile painted by James Hutton on one of his trips through the Scottish countryside.

14. Identify which layer in the painting is the youngest.
15. Identify which layer represents older rock—A or B. Justify your decision.
16. Why do you think the strata in the painting are tilted?
17. Identify the proper name of the surface labelled D.
18. Describe a process that may have created D.
19. Rock structure E cuts across several sedimentary layers. Describe how structure E may have formed.
20. Is structure E younger or older than the rock in layer A? Justify your decision.

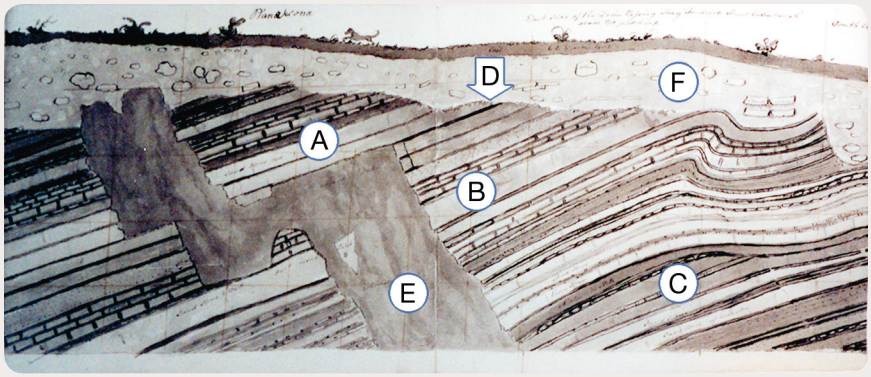


Figure C1.33: James Hutton painted geological profiles.

A Self-Sustaining System

Hutton published his theory that the geological process of Earth operates as a self-sustained system. He suggested that a subterranean fire deep within Earth provides a perpetual source of energy that creates and destroys material from the crust—Earth is a system that can remain in balance. Hutton's thinking started the modern understanding of how rocks form.

In the next activity you will see Hutton's theory in action by watching the applet "How Do Rocks Undergo Change?" from the Science 20 Textbook CD. Before you begin the applet, review the characteristics of the three basic types of rock you studied in previous science courses.

Type of Rock	How Formed	Where Formed	Example
Sedimentary	Sedimentary rock consists of eroded fragments of other rock types. The layers of sediment are compressed.	Sedimentary rocks are formed at the surface of Earth under relatively low temperatures.	
Igneous	Igneous rock forms when molten magma from the mantle intrudes into the crust or extrudes onto the surface.	Igneous rocks are formed deep within Earth's crust and mantle under extreme heat. The whole mantle consists of igneous rock.	
Metamorphic	Metamorphic rock forms when sedimentary or igneous rock is transformed at the molecular level by intense pressure and heat.	Metamorphic rocks are often formed at the sites of collisions between crustal plates.	

Utilizing Technology

How Do Rocks Undergo Change?

Purpose

You will observe the path of a rock travelling through the rock cycle and be able to summarize your learning by completing a rock-cycle diagram.

Science Skills

✓ Analyzing and Interpreting

Procedure

step 1: Explore the interactive features of the applet titled "How Do Rocks Undergo Change?" on the Science 20 Textbook CD by watching the main computer animations as well as the detailed visualizations.

step 2: Complete the rock-cycle diagram as directed at the end of the applet.

Analysis

Compare your rock-cycle diagram with other diagrams.

The Rock Cycle

As shown in the applet, rocks undergo change through a process called the **rock cycle**.

rock cycle: a concept that relates the continual change of rocks from one type to another

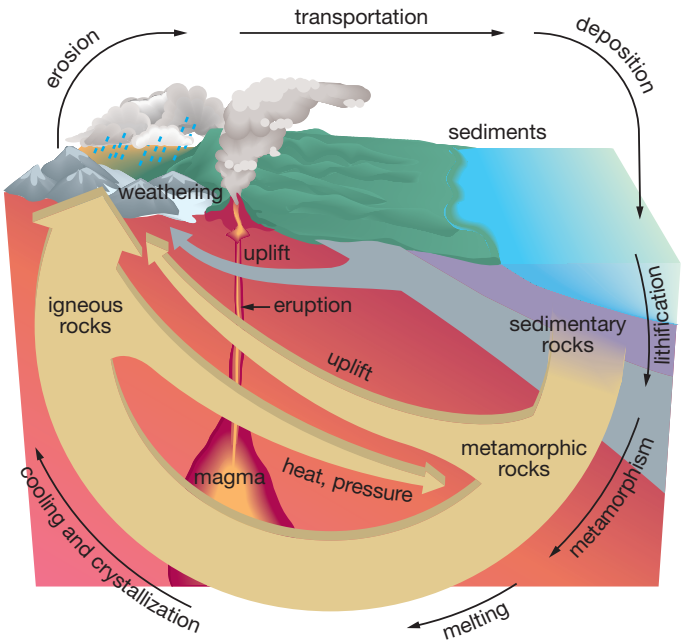


Figure C1.34: Rocks change by a process called the rock cycle.

According to Hutton, all rocks start out as molten magma within Earth's mantle. This magma cools and solidifies on or near the surface to form igneous rock. Rock on the surface is then weathered and eroded by water, wind, and ice to form sediments, which are later deposited to form sedimentary rock. Sedimentary rocks and igneous rocks can be transformed by extreme heat and pressure to become metamorphic rocks. Eventually, all rocks melt and return to the mantle. This is a perpetual, balanced cycle driven by energy released by nuclear reactions in Earth's core.

The Rise of Uniformitarianism

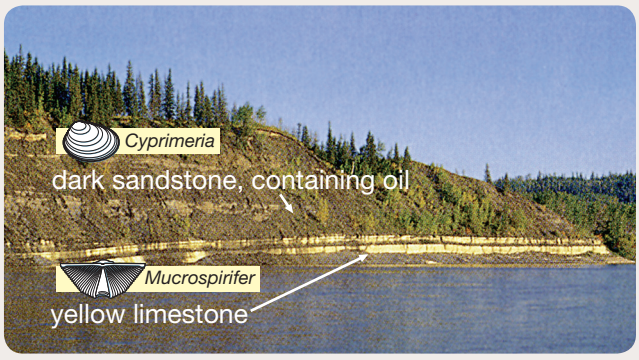
Hutton's theories took a long time to catch on in the scientific community. His theory of uniformitarianism was buried in a 2000-page book filled with difficult language. The geologist who brought Hutton's uniformitarianism to the forefront was Charles Lyell (1797–1875). Lyell added to Hutton's evidence and, using a much more readable style, continued to argue that geological evidence supported the theory of uniformitarianism.

He argued that processes, such as erosion, sediment deposition, volcanic action, and earthquakes have operated in fundamentally the same manner and intensity throughout Earth's history. Lyell helped build the Geological Time Scale by using index fossils. Lyell's methods and writing style greatly influenced young scientists, such as Charles Darwin.

Investigation

The Fort McMurray Unconformity

A striking contrast can be observed within the rock formations revealed along the Athabasca River. In one location, a brown layer of oil sandstone lies above a layer of bright-yellow limestone.



Purpose

You will account for the sudden change in colour between the yellow and dark-brown layers of the river bank.

Background Information

Figure C1.35: This is Mucrospirifer's environment.

As shown on the previous page, the dark, oily sandstone sits atop bright-yellow limestone, which is only deposited in warm oceans. The yellow limestone contains the Devonian marine fossil Mucrospirifer (a brachiopod). The oily sandstone lying atop the limestone contains the Cretaceous Period marine fossil Cyprimeria. This fossil lived near coastal river deltas.

Analysis

1. Use the Geological Time Scale to list the periods missing from Fort McMurray's geological record.
2. Determine the minimum number of years missing from the record.
3. Identify the proper name of the surface between the yellow and dark-brown layers.

Science Skills

✓ Analyzing and Interpreting

Research

4. Analyze which geological processes could account for the sudden change in colour between the yellow and dark-brown layers on the Athabasca River bank near Fort McMurray. Use the Internet to collect information. Your answer should take the form of a brief story about the geological history of the Fort McMurray area. Include the cause of the unconformity. Was the cause catastrophic, or does it fit better with the theory of uniformitarianism? Support your account with evidence.

1.4 Summary

Studying Earth's history is challenging because it occurs on such a large scale—billions of years are recorded in thousands of rock layers. A careful observation of processes that yield barely noticeable changes over an entire lifetime is required. Yet, these processes are relentless. Given enough time, they have completely changed the face of Earth many times.

As you'll see in Chapter 2, geologists suspect that Alberta's resource wealth, whether in oil sands or conventional petroleum reserves, can be traced back to microscopic plants and animals that lived in warm tropical seas more than 300 million years ago. It is speculated that the work of bacteria, followed by millions of years of heat and pressure, transformed the organic matter into Alberta's black gold.

Hutton's and Lyell's theory of uniformitarianism stated that the changes of the past could be explained by geological processes still in operation. Many of these processes are summarized in the rock cycle, which explains how the three major rock types—igneous, sedimentary, and metamorphic—form and change. These two scientists also helped to show that rock strata forms a record that has taken millions of years to develop.

1.4 Questions

Knowledge

1. Define *catastrophism*.

2. Define *uniformitarianism*.

3. Why did James Hutton believe Earth was infinitely old?

4. How does each of the three main rock types form?

Applying Concepts

Use Figure C1.36 to answer questions 5 to 9.

5. Determine which fossil in Diagram 1 is older—the one in A or B. Explain your reasoning.

6. List the layers in Diagram 2 from oldest to youngest.

7. Explain the cause of unconformity in Diagram 2.

8. Determine which layer in Diagram 2 is approximately the same age as layer A in Diagram 1. How can you tell?

9. Based on the rock strata, relate a brief story that explains the geological history of the land area shown in Diagram 3.

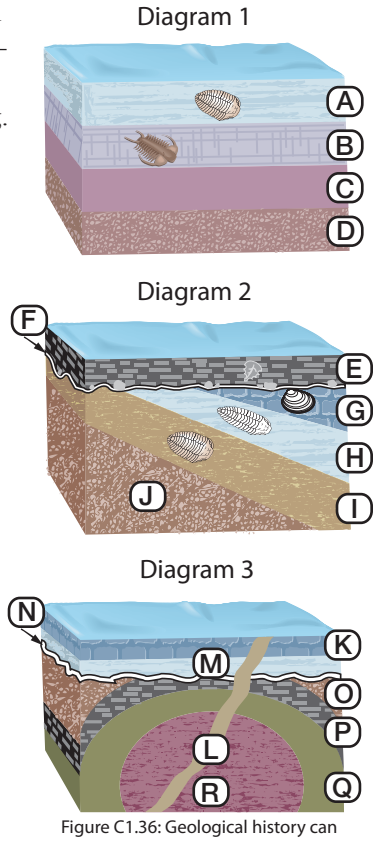


Figure C1.36: Geological history can be told by observing fossils.